An international study of the factors associated with the acceptability of advanced rider assistive systems for powered two-wheelers

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Abstract

Although the use of advanced driver assistive systems in passenger vehicles is becoming increasingly widespread, there has been limited development of equivalent systems in powered two-wheelers (PTWs). One reason for this is that the development and deployment of advanced rider assistive systems has been met with resistance from many PTW rider groups, despite research suggesting that assistive systems could potentially reduce the number and severity of PTW crashes. A large-scale survey on PTW riders' acceptance of assistive systems was conducted across Europe and Australia as part of the European Commission Two-wheeler Behaviour and Safety (2-Be-Safe) project. The sample included 6297 respondents (257 Australians), who were typically frequent riders and rode primarily for leisure purposes. Several individual traits predicted overall levels of acceptability of assistive systems in general, including self-reported risky riding practices and attitudes towards rule-breaking and speeding. Overall levels of acceptability were relatively low; however, acceptability levels varied considerably between specific systems. Acceptability was highest for systems that are well known and considered reliable (e.g., night vision, ABS) and lowest for systems that interfere with the task of riding (e.g., ISA, adaptive cruise control). The results indicate that riders remain resistant to the use of assistive systems and highlight several barriers to the uptake of assistive systems by PTW riders, but also suggest possible strategies for overcoming these barriers and ultimately improving riders' acceptance of PTW assistive systems.

Introduction

Motorcycles comprise 4.2% of registered vehicles and account for 0.8% of vehicle kilometres travelled in Australia (ABS, 2013b), but motorcyclists represent 13.8% of fatalities on our roads (ABS, 2013a). Although the absolute number of fatalities per 10,000 motorcycles has been decreasing in Australia, motorcycle fatalities have not been decreasing at the same rate as the total road toll, indicating that overall gains in road safety have not produced equivalent benefits for riders of powered two-wheelers (PTWs; Haworth, 2012). Similar patterns have been observed in many developed countries, particularly in Europe and North America, prompting calls for research into the underlying causes and potential solutions to reduce the prevalence and severity of these crashes. To this end, the European Commission recently co-funded an extensive world-first three year program of human factors research into Two-wheeler Behaviour and Safety ("2-Be-Safe"). Involving coordinated efforts from 29 research partners across 14 countries throughout Europe, Israel and Australia, 2-Be-Safe addressed several distinct but related aspects of PTW safety including in-depth crash analysis, increasing the conspicuity of motorcycles to other road users, and development and promotion of PTW-specific assistive systems and intelligent transport systems.

One potential method for reducing the incidence and severity of PTW crashes is through the development of safety-enhancing assistive systems for PTWs, equivalent to those already available for four-wheeled vehicles (Bayly et al., 2006; Regan et al., 2001). PTW assistive systems are intended to address issues relating to transportation safety and/or efficiency and combine elements of information processing, communications, vehicle sensing and control. Table 1 provides a descriptive list of 18 existing or emerging PTW assistive systems. Detailed discussions of PTW assistive systems have been published elsewhere (e.g., Bayly et al., 2006; Pauzié & Guillot, 2008), with researchers repeatedly noting that there currently exist very few PTW-specific systems.

Table 1. Descriptive list of PTW assistive systems

System	Description of functionality
Adaptive cruise control	Assistive system; adapts the distance to the vehicle ahead automatically
Advanced front-lighting system	Continuously adapts headlamp illumination according to the riding situation and ambient light
Airbag	Autonomous post-crash system; vehicle-mounted airbag is deployed in the event of a crash
Anti-lock braking system (ABS)	Autonomous braking system; prevents the wheels from locking when braking, especially on wet or slippery road surface
Blind spot monitor	Warning system; detects other vehicles located to the rider's side and rear
Collision warning system	Warning system; warns the rider of any dangers that may lie ahead on the road
Combined braking systems	Autonomous braking system; application of one brake control will activate both front and rear brakes, e.g. using automatic brake force distribution
Curve speed warning system	Warning system; Warns the rider if s/he enters a curve at a speed that is too fast to negotiate the curve safely
Emergency brake assistance	Autonomous braking system; Ensures maximum braking power in an emergency situation
eCall (Automatic crash notification)	Autonomous post-crash system; sends vehicle information (e.g., GPS coordinates) to local emergency services in the event of a crash, in order to bring rapid assistance to riders
GPS navigation	Informative system
Intelligent speed adaptation (ISA)	Assistive system; Monitors vehicle speed and local speed limit and either warns the rider (advisory ISA) or reduces speed (limiting ISA) when the vehicle is detected to be exceeding the speed limit
Lane keeping assistant	Assistive system; monitors vehicle lane position and warns the rider when the vehicle begins to move out of its lane
Night vision	Informative system; Vision enhancement systems provide an augmented view of the road environment and may employ radar, laser or infrared imaging to detect objects on the road
Slipper clutch/back-torque limiter	Autonomous system; Specialized clutch to mitigate the effects of engine braking when riders decelerate as they enter corners
Traction control system	Autonomous system; Intervenes and prevents the vehicle from sliding on loose or slippery surfaces
Tyre pressure control system	Warning system; Displays the air pressure and/or temperature measured in the tyres
Vacuum servo	Autonomous braking system; Provides assistance to the rider by decreasing the braking effort

Although it is important to evaluate and demonstrate the technical effectiveness of assistive systems, in order for these systems to yield practical benefits they must be deemed acceptable by their intended end users (i.e., PTW riders). *Acceptability* refers to the idea that a system meets the end user's requirements and that they are willing to use it (Nielsen, 1993). Several models of acceptability have been proposed, which vary slightly in their specifics but identify common factors under two overarching themes: general and system-specific predictors of acceptability (Vlassenroot et al., 2010). General or distal predictors are factors that influence acceptability indirectly through the broader social environmental context in which the system is used, which determine whether an individual will find assistive systems in general acceptable. These include: social norms; personal and social aims; problem perception; information and/or knowledge about the problem; responsibility awareness; and attitudes to riding behaviour, including speeding and safety (Schade, 2005; Vlassenroot et al., 2010). For example, if a PTW rider does not perceive that they have a problem with safety, then they may exhibit lower acceptability of assistive systems because they deem them unnecessary. System-specific or proximal predictors refer to characteristics of individual systems that determine whether individuals will find a particular system acceptable (Schade, 2005; Vlassenroot et al., 2010). These include factors such as perceived system usability, effectiveness, affordability, satisfaction and equity.

There has been limited previous research on the acceptability of PTW assistive systems. Most existing research has focused on intelligent speed adaptation (ISA), with typical results being that most riders express strongly negative views against ISA (Cairney & Ritzinger, 2008; Nordqvist & Gregersen, 2011; Simpkin et al., 2007). In contrast, research on car drivers typically produces neutral or even positive attitudes towards ISA (e.g., Regan et al., 2006), highlighting fundamental differences between riding and driving populations in typical attitudes towards assistive systems.

In addition to ISA, previous research on PTW assistive systems has also examined the acceptability of anti-lock braking systems (ABS), collision warning systems, curve speed warning systems and automatic crash notification systems (called eCall in Europe). Attitudes towards ABS are typically positive, with the majority of riders now seeking to buy vehicles with ABS, although some riders express concern regarding its affordability for smaller and cheaper vehicles (Cairney & Ritzinger, 2008; McCartt et al., 2011; Nordqvist & Gregersen, 2011). Results regarding collision warning and curve speed warning systems are less clear. Previous research used very small samples (n = 10) and although most riders indicated willingness to adopt these systems they expressed unwillingness to pay more than €250 and wanted an option to disable the system (Biral et al., 2010; Huth et al., 2012; Montanari et al., 2011). Only one study has examined the acceptability of automatic crash notification (Cairney & Ritzinger, 2008); this research found that although riders could see benefits to using the system, they expressed concerns regarding its effectiveness and affordability.

Most previous research on acceptability of PTW assistive systems has used small sample sizes and has examined a limited range of systems, with the majority of studies examining a single system in isolation. As such, there is a need for more comprehensive contemporary research on riders' acceptability of PTW assistive systems. The current study was designed to examine both general and system-specific predictors of acceptability towards PTW assistive systems, by measuring riders' attitudes towards a wide range of assistive systems in a large-scale international online survey. General predictors of acceptability were measured by assessing which characteristics (e.g., safety attitudes, risky riding practices, and personality traits) that predicted individuals' overall levels of acceptability. System-specific predictors of acceptability were measured by comparing acceptability across different systems.

Method

Participants

The survey attracted 6297 respondents (93.2% male; M_{age} = 43.0 years, SD = 12.0) from countries including Australia (n = 257), Austria (n = 32), Czech Republic (n = 3), Finland (n = 212), France (n = 1578), Greece (n = 456), Germany (n = 203), Portugal (n = 499), Spain (n = 7) and the United Kingdom (n = 2290). The sample was comprised primarily of motorcycle riders (rather than scooter riders). Most respondents were members of motorcycling organisations (60%) and rode at least 3 times per week (66%) for the purposes of both leisure (personal enjoyment 88%; trips 68%) and commuting (69%).

Survey administration

The survey was administered online in seven languages (Czech, English, Finnish, French, German, Greek, and Portuguese) and was available for a four-week period. Pilot testing revealed that completion times for the full survey ranged from 12 to 61 minutes with a median of 24 minutes. Recruitment was conducted online through several PTW rider organisations including the Federation of European Motorcyclists' Associations (FEMA) and its member organisations.

Survey content

The survey consisted of three sections (see Lenné et al., 2011, for full details). Section 1 assessed socio-demographic characteristics (e.g., age, sex), riding practices and accident history. Section 2 assessed the relationship between personality traits and safety attitudes, based on previous questionnaires (Chen, 2009; Ulleberg & Rundmo, 2003).

Section 3 examined acceptability of various PTW assistive systems and comprised five subsections. The first four subsections assessed detailed attitudes towards four types of assistive systems: braking enhancing systems; traction control; distance keeping; and navigation systems. Each subsection began with a brief description of a critical riding situation, in which a specific type of assistive system might be helpful. Respondents were asked to read the scenario and then rate their agreement with a series of statements about the advantages (e.g., "Such a system would prevent critical situations") and disadvantages (e.g., "Such a system may lead to riskier riding behaviour") of the system on a 5-point scale from 1 (I do not agree) to 5 (I agree totally). The scenarios, statements and systems used in Section 3 of the survey were based on the results of prior focus group interviews, which were conducted as part of the 2-Be-Safe project to understand riders' attitudes and concerns regarding assistive systems.

The fifth subsection of Section 3 assessed the acceptability of a broader range of assistive systems. Respondents read a list of 18 assistive systems, containing brief functional explanations of each system (see Table 1), and were asked to indicate the importance of each system for improving motorcycling safety on a 5-point scale from 1 (not important) to 5 (important). Greater acceptability is indicated by higher ratings of importance. Perceived importance captures multiple aspects of acceptability, including problem perception and awareness, personal and social aims, system usability and effectiveness. For example, if problem perception, usability and effectiveness are low, or if the system is incompatible with the individual's personal and social aims, this would manifest in low importance ratings for that system. As such, importance is both a necessary precursor to acceptability and a useful single-item proxy measure that captures multiple aspects of acceptability.

Data analysis

To assess system-specific predictors of acceptability, the varying levels of acceptability measured in Section 3 were compared between systems. To assess general predictors of acceptability (i.e., individual differences) two-step cluster analysis was used to assign individuals to groups based on their scores on four acceptability indices, which were calculated for the four assistive systems (braking enhancing systems, traction control, distance keeping, and navigation systems) examined in Section 3. Each index was calculated by averaging the scale items for the relevant system, i.e., respondents' relative agreement with statements regarding the advantages and disadvantages of each system. Negative statements were reverse-coded. The acceptability indices comprise a score between 1 (low) and 5 (high) indicating the overall acceptability of each system. The resulting clusters were then compared on variables measured in Sections 1 and 2 to assess which of these variables best predicted overall acceptability of PTW assistive systems.

Given the large sample size, statistical significance is not a reliable indicator of meaningful effects. Consequently, pairwise comparisons also include effect size correlation (r) for scale variables and Cramer's V for categorical variables. Both are measures of association that range from 0 to 1: .1 indicates small associations; .3 moderate associations; and ≥.5 large associations. For ANOVAs partial eta squared (n_p^2) is reported; this is a measure of effect size where .01 indicates a small effect, .06 indicates a medium effect and .14 indicates a large effect. Where appropriate, corrected degrees of freedom are reported for t-tests and ANOVAs.

Detailed analyses of the full dataset have been presented elsewhere (Beanland et al., 2013). We are yet to explore how the Australian respondents differed from the broader European sample. The current paper presents this new analysis.

Results

Sample demographics

The demographic characteristics of Australian respondents differed from the European sample. The Australian sample had a higher proportion of females: 14.4% of Australians were female compared to 6.1% of Europeans, $\chi^2(1) = 28.32$, $p < .0005$, $V = .067$. The Australian sample was also older than the European sample (Australians: $M = 52.4$ years, $SD = 10.4$; Europeans: $M = 42.6$, $SD = 11.9$), $t(285.4) = -14.68$, $p < .0005$, $r = .66$.

Australian respondents reported riding less frequently than Europeans, $\chi^2(4) = 112.72$, $p < .0005$, $V = .134$. Most Europeans (66.9%) reported riding most days of the week, whereas most Australians (59.9%) rode 2 days a week or less. This appears to be a result of different reasons for riding: Australian respondents were less likely to report using their PTW for day-to-day activities such as commuting (43.2% vs. 70.0%), $\chi^2(1) = 82.57$, $p < .0005$, $V = .115$, or shopping (25.3% vs. 40.9%), $\chi^2(1) = 24.85$, $p < .0005$, $V = .063$. There were no between-groups differences in the likelihood of using a PTW for trips, fun, race track riding, training tracks or off-road riding.

Awareness of assistive systems

Overall awareness of assistive systems was high; for all systems, fewer than 10% of the overall sample reported that they had no knowledge of that particular system. Awareness was highest for systems that are already widely available, such as ABS (Europeans: 97.9% aware; Australians: 98.4% aware) and GPS (Europeans: 98.7% aware; Australians: 98.8% aware). The Australian sample reported slightly lower awareness of airbags, slipper clutch, adaptive cruise control and lane keeping assistants, but the difference was only statistically significant for airbags (Europeans: 94.7% aware; Australians 91.8% aware), $\chi^2(1) = 4.08$, $p = .048$, $V = .025$.

System-specific influences on acceptability

Acceptability ratings varied significantly between systems, $F(12.6, 58688.7) = 255.36$, $p < .005$, $n_p^2 = .052$. Mean ratings across the whole sample ranged from 1.69 to 3.79, where 1 indicates low acceptability and 5 indicates high acceptability.

Nine systems had overall mean acceptability ratings that were less than three, indicating low acceptability: adaptive cruise control (1.69), lane keeping assistant (1.78); intelligent speed adaptation (1.80); curve speed warning (2.34); collision warning (2.52); airbag (2.61); vacuum servo (2.69); slipper clutch (2.75); and blind spot monitor (2.87).

The other nine systems had mean acceptability ratings between 3 and 4, indicating moderate acceptability: GPS (3.05); combined braking systems (3.07); traction control (3.12); emergency brake assistance (3.13); tyre pressure control (3.23); eCall (3.42); ABS (3.60); advanced front-lighting (3.62); and night vision (3.79).

There was a significant difference between the ratings of Australian and European respondents, $F(1, 4665) = 31.28$, $p < .0005$, $\eta_p^2 = .007$. For all but one system (vacuum servo), acceptability was significantly higher among Australians compared to Europeans (see Table 2). There was an interaction between location (Australia vs. Europe) and system, $F(12.6, 58688.7) = 7.48$, $p < .005$, $n_p^2 = .002$, indicating that the relative ratings of systems differed between Australia and the rest of the sample. The systems with the three lowest (adaptive cruise control, lane keeping assistant, ISA) and highest (night vision, ABS, advanced front-lighting) ratings were the same in Australia and Europe, but the order of the middle-ranked systems varied between countries.

Table 2. Overall mean (and SD) acceptability rating for each assistive system (1 = low, 5 = high), comparing European and Australian respondents

System	Europeans	Australians	Significance	*r*
Informative systems				
GPS navigation	2.99 (1.42)	3.40 (1.40)	$t(275.6) = -4.56, p < .0005$	.26#
Night vision	3.80 (1.38)	4.32 (0.91)	$t(278.8) = -8.28, p < .0005$	.44##
Warning systems				
Blind spot monitor	2.85 (1.56)	3.32 (1.51)	$t(261.8) = -4.68, p < .0005$	.28#
Collision warning system	2.48 (1.45)	3.18 (1.51)	$t(256.1) = -7.03, p < .0005$	.40##
Curve speed warning system	2.29 (1.38)	2.80 (1.50)	$t(247.9) = -5.11, p < .0005$	.31##
Tyre pressure control system	3.20 (1.48)	3.46 (1.36)	$t(272.4) = -2.95, p = .003$	.18#
Intervening systems (take over part of the riding task)				
Adaptive cruise control	1.62 (1.06)	2.09 (1.32)	$t(249.7) = -5.40, p < .0005$	.32##
Intelligent speed adaptation	1.74 (1.16)	2.30 (1.44)	$t(256.7) = -5.94, p < .0005$	.35##
Lane keeping assistant	1.72 (1.14)	2.32 (1.40)	$t(250.2) = -6.45, p < .0005$	.38##
Fully autonomous systems (act without input from the rider)				
Advanced front-lighting system	3.60 (1.43)	4.02 (1.12)	$t(268.5) = -5.63, p < .0005$	.32##
Airbag	2.60 (1.51)	2.33 (1.35)	$t(259.8) = 2.93, p = .004$	.18#
Anti-lock braking system	3.61 (1.49)	4.09 (1.25)	$t(283.5) = -5.82, p < .0005$	.33##
Combined braking systems	3.08 (1.55)	3.35 (1.47)	$t(273.3) = -2.82, p = .005$	.17#
eCall	3.41 (1.48)	3.67 (1.31)	$t(270.2) = -2.98$, p = .003	.18#
Emergency brake assistance	3.12 (1.56)	3.76 (1.32)	$t(275.6) = -7.37, p < .0005$	.41##
Slipper clutch	2.69 (1.46)	3.26 (1.39)	$t(247.0) = -5.98, p < .0005$	.36##
Traction control system	3.09 (1.51)	3.75 (1.33)	$t(270.1) = -7.59, p < .0005$	.42##
Vacuum servo	2.66 (1.49)	2.77 (1.47)	$t(258.4) = -1.10, p = .271$	.07

# indicates small effect sizes ($r \geq .1$); ## indicates moderate effect sizes ($r \geq .3$)

General influences on acceptability

Two-step cluster analysis was used to reveal distinct groups of respondents based on their levels of acceptability for the four systems that were examined in-depth (as represented by the four acceptability indices). This analysis yielded two groups, which were labelled *low acceptability* and *moderate acceptability*. Australians were significantly more likely than Europeans to be in the moderate acceptability group (85.9% vs. 61.4%), $\chi^2(1) = 61.37$, $p < .0005$, $V = .100$, consistent with the results that Australians demonstrated higher levels of acceptability for all systems.

Respondents in the low acceptability cluster gave mean acceptability ratings ranging from 1.1 (adaptive cruise control) to 3.03 (night vision), whereas ratings by the moderate acceptability cluster ranged from 1.96 (adaptive cruise control) to 4.38 (ABS). There were significant differences in acceptability ratings between clusters for all systems, with moderate ($r \geq .3$) to large ($r \geq .5$) effect sizes for all comparisons. The largest differences observed were for ABS (r = .71), traction control (r = .70), emergency brake assistance (r = .64), combined braking systems (r = .61), curve speed warning (r = .54), advanced front-lighting system (r = .52), night vision (r = .51), airbags (r = .51) and collision warning systems (r = .51).

Riding attitudes that predict acceptability

Respondents rated their agreement with 19 statements relating to attitudes towards rule-breaking and risk-taking while riding. Attitudes were rated on a 5-point scale from 1 (do not agree) to 5 (totally agree) and behaviours were rated on a 5-point scale from 1 (never) to 5 (very often). These statements were analysed using ANOVA with the 19 statements as within-subjects factors and cluster membership (low, moderate) and location (Australia, Europe) as between-subjects factors. This analysis revealed a main effect of location: Australians reported more risky behaviours and attitudes than Europeans, $F(1, 5164) = 33.94$, $p < .0005$, $\eta_p^2 = .007$. There was no main effect of cluster membership, $F(1, 5164) = 1.02$, $p = .312$, $\eta_p^2 = .000$, but there was a significant cluster x location interaction, $F(1, 5164) = 43.22$, $p < .0005$, $\eta_p^2 = .008$ (see Fig. 1).

Figure 1. Overall levels of self-reported risky riding attitudes and behaviour, by acceptability cluster and geographic location

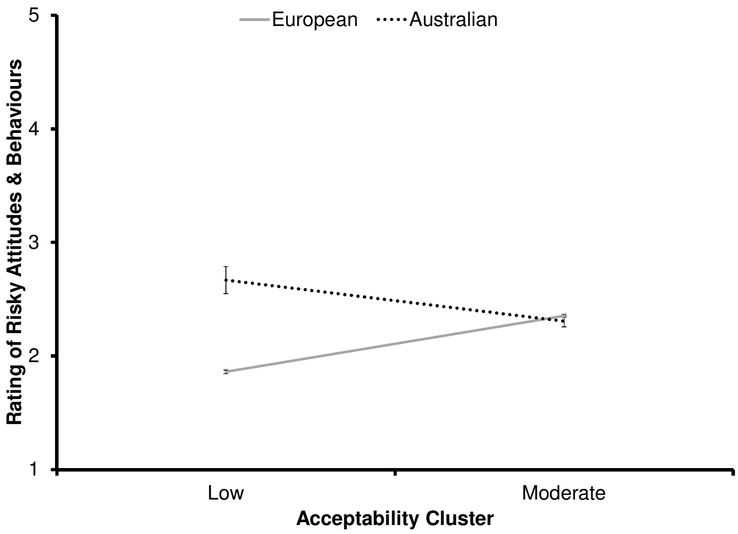

Table 3. Mean (and SD) ratings for risky attitudes and behaviours that differed significantly between the low and moderate acceptability clusters

Statement	Acceptability Cluster		Significance		
	Low	Moderate	*t*-test	*p*	*r*
If something works, it is less important whether it is right or wrong	3.09 (1.40)	2.55 (1.20)	$t(41.8) = 2.11$	.041	.31
There are many traffic rules which cannot be obeyed in order to keep up the traffic flow	3.56 (1.26)	3.07 (1.34)	$t(46.8) = 2.07$	.044	.29
Sometimes it is necessary to bend the traffic rules to arrive in time	3.21 (1.32)	2.63 (1.25)	$t(43.8) = 2.36$	.023	.34
A person who take chances and violate some traffic rules is not necessary a less safe rider	3.88 (1.37)	3.20 (1.34)	$t(44.7) = 2.71$	.010	.38
If you are a safe rider, it is acceptable to exceed the speed limit by 20 km/h	3.00 (1.54)	2.33 (1.40)	$t(42.9) = 2.38$	.022	.34
Overtake the car in front when it is driving at the speed limit	3.74 (1.29)	3.12 (1.30)	$t(45.4) = 2.57$	.014	.36

Pairwise comparisons on each of the 19 statements revealed in the European sample, for every statement the moderate acceptability cluster scored significantly *higher* than the low acceptability cluster. Comparisons with moderate effect sizes ($r \geq .3$) involved statements indicating greater endorsement of speeding, disregard for traffic rules and a need for fun or excitement.

Conversely, for the Australian sample the moderate acceptability cluster scored *lower* than the low acceptability cluster on all but one statement. Comparisons where this difference was statistically significant are reported in Table 3. These statements particularly relate to the idea that it is permissible to break rules as long as it does not compromise safety and that it is possible to safely exceed the speed limit or break rules.

Discussion

The aim of the current study was to examine general and system-specific predictors of acceptability for PTW assistive systems, with a particular focus on identifying any substantial differences between Australian and European riders. Regarding system-specific predictors of acceptability, although the relative rankings of systems differ slightly across countries the major system-specific influences on acceptability appear to be relatively constant across countries. In particular, intervening systems that take over part of the riding task (e.g., ISA, adaptive cruise control, lane keeping assistant) had the lowest acceptability in every country. The systems that had the highest acceptability overall included: those that are purely informative (night vision, GPS); braking and traction control systems that activate in emergency situations only; and eCall. This suggests that riders are likely to be most receptive to systems that have obvious safety benefits, provided that these systems either do not intervene with the fundamental riding task or only intervene in emergency situations.

Although acceptability levels varied significantly between systems, there were several individual characteristics that predicted acceptability of PTW assistive systems in general. Interestingly, these general predictors of acceptability differed significantly between Australian and European riders. Among the European sample, riders who displayed higher acceptability self-reported that they were more likely to engage in risky riding practices. There are two possible interpretations for this finding. First, it could be that riders who engage in more risk-taking are more willing to accept assistive systems, consistent with risk homeostasis theories. Alternatively, it could be that riders with low acceptability downplay their own personal risk and likelihood of crashing (Beanland et al., 2013). In contrast, the Australian sample showed a more straightforward relationship between risky behaviour and acceptability: riders who reported higher engagement in risk-taking behaviours also reported lower levels of acceptability. This is consistent with the idea that these riders are opposed to assistive systems that interfere with the riding task, particularly the aspects of riding that these individuals find most enjoyable (such as the ability to ride at high speed when they consider it safe to do so). However, it is worth noting that while the Australian sample reported higher levels of risk-taking behaviour, they also reported higher overall levels of acceptability towards assistive systems than did Europeans.

The differences in acceptability between Australians and Europeans cannot be explained by differences in the availability or awareness of assistive systems between countries, given that both groups showed very high awareness of all systems. One possibility is that these differences occurred because different subtypes of riders were represented in Australia. Notably the Australian sample consisted of individuals who primarily rode on weekends for leisure purposes, whereas the European respondents rode significantly more often because they also used their PTWs for commuting and day-to-day pursuits such as shopping. As such, rather than reflecting cultural differences between *countries*, the different patterns in the relationship between risk-taking and acceptability might reflect cultural differences between subpopulations of riders. If this were the case, then it has implications for the promotion of assistive systems: in particular, it would suggest that slightly different strategies should be adopted when promoting assistive systems to commuters versus leisure riders, since they have different reasons for resisting assistive systems. For leisure riders, as discussed above, assistive systems may be viewed as "ruining their fun" and detracting from the fundamental task of riding. For commuters, on the other hand, if they are less likely to engage in risk-taking behaviour they may simply perceive assistive systems as unnecessary (particularly for systems that are relatively expensive in comparison to the cost of a standard PTW).

Previous research has explicitly attempted to identify which PTW assistive systems are likely to have the greatest safety benefits in Australia (Bayly et al., 2006). Several of these systems already have moderate levels of acceptability in Australia, including ABS, combined braking systems, emergency brake assist, traction control and automatic crash notification (eCall). Other systems that could have significant safety benefits currently have low acceptability, particularly ISA, airbags and (to a lesser extent) curve speed warning. In some cases it may be possible to increase acceptability by providing riders with empirical information regarding the effectiveness of these systems; the current acceptability of ABS, for example, suggests that riders will be willing to adopt systems that they regard as effective and reliable. As such, there is a clear need to develop strong lines of communication between researchers who evaluate assistive systems and the intended users of these systems in the PTW riding community, in order to make riders explicitly aware of demonstrated safety benefits of these systems. Where safety benefits have not yet been demonstrated, more research should be undertaken to develop an evidence base regarding the effectiveness of assistive systems. In particular, it would be useful to conduct evaluations of assistive systems that compare the relative benefits of emerging technologies to both existing systems and non-technological strategies for safety improvement, such as rider training, in order to provide the most convincing evidence possible.

Although developing a strong evidence base regarding safety benefits will help improve the acceptability of some assistive systems, it is worth noting that other systems are likely to face continued resistance among many riders. This is particularly likely for systems that interfere with the riding task and/or directly affect the speed of PTWs, such as ISA, adaptive cruise control and lane keeping assist. Therefore increasing the acceptability of ISA among PTW riders is unlikely to be a trivial task, and will require much more focused efforts in order to engage the riding community, identify their most prominent concerns regarding the system and identify possible strategies for addressing those concerns.

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